

Comparison of pre-post operation of cardiac outputs in breast reduction with Simpson's rule and Teichholz's formula

Cardiac outputs in breast reduction

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Abstract

Aim: This study aims to compare pre- and post-operative cardiac outputs in patients undergoing breast reduction surgery using Simpson's rule and Teichholz's formula. The assessment focuses on ejection fraction (EF), end-systolic volume (ESV), end-diastolic volume (EDV), and stroke volume (SV).

Material and Methods: Comparisons across the repeated measurements (pre and post operation values for EF, EDV, ESV and SV) were made by either using Paired Samples t-test or Wilcoxon signed-rank tests.

Results: Statistically significant differences were observed in EF, EDV, and SV pre- and post-operative mean scores using the Simpson method ($p < 0.001$, $p = 0.004$, $p < 0.001$, respectively). No significant difference was found for ESV ($p = 0.061$). Using the Teichholz method, significant differences were found in EF, ESV, and SV ($p < 0.001$, $p < 0.001$, $p < 0.001$), but not for EDV ($p = 0.646$). According to Bland-Altman graphics, pre-post measurements were within the limits of agreement in all cardiac outputs.

Discussion: Numerous studies in the literature have demonstrated the positive effects of breast reduction surgery on both aesthetic and functional health. Our study makes a significant contribution by revealing the positive impact of this surgery on cardiac performance. Our findings underscore the cardiac benefits of breast reduction surgery and support its role in enhancing overall patient well-being. Future research could investigate in greater detail the long-term cardiovascular benefits and potential respiratory improvements associated with this procedure.

Keywords

Breast Reduction, Simpson Rule, Teichholz Formula, Cardiac Outputs

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This study was approved by the Ethics Committee of Antalya Education and Research Hospital (Date: 2013-02-28, No: 15/6)

Introduction

Breast reduction is one of the most important and most common operations [1]. Body Mass Index (BMI) is above average in the majority of the patients diagnosed with macromastia, which causes limitations in both their daily and social activities [2]. Patients with macromastia frequently experience symptoms such as shoulder, neck, and back pain, rash in the inframammary fold, and kyphosis. Breast reduction surgery provides patients with both aesthetic and functional benefits. Obesity, smoking, advanced age, and comorbidities commonly observed in these patients are reported to be associated with postoperative complications and increased postoperative risks [3-5]. There is extensive research on breast reduction surgery; some studies focus on pulmonary function after reduction [6, 7]. However, none of these studies have investigated the effects of breast reduction surgery on cardiac ejection fraction. This study aimed to investigate the effects of breast reduction surgery on cardiac ejection fraction using two different methods.

Material and Methods

The patients diagnosed with macromastia at the plastic and reconstructive surgery clinic of Antalya Education and Research Hospital between March 2013 and January 2014 underwent preoperative and postoperative echocardiographic examinations three weeks apart. Data on ejection fraction (EF), end-systolic volume (ESV), end-diastolic volume (EDV), and stroke volume (SV) parameters were collected using the Teichholz method and Modified Simpson method.

The Teichholz method formulas are as follows

SV = LVEDV - LVESV

$V = 7 / (2.4 + D) \times D^3$

EF = (LVEDV - LVESV) / LVEDV x 100%

(V: volume, D: represents diameter, LV: left ventricle, LVEDV: left ventricular end-diastolic volume, LVESV: left ventricular end-systolic volume, and EF: ejection fraction.)

The formulas for the Modified Simpson method are as follows:

EF = (EDV - ESV) / ESV x 100%

(EDV: end-diastolic volume, ESV: end-systolic volume, and EF: ejection fraction)

All the patients were applied Wise pattern inferior pedicle technique, and all the patients underwent transthoracic echocardiography. M-mod standard two-dimension (2DE) left parasternal long axis echocardiographic investigation was performed. Left ventricle inner dimensions [end-systolic diameter (ESD) and end-diastole (EDD)] were performed according to the recommendations of the American Society of Echocardiography. It was investigated via two methods in echocardiography (Teichholz, Simpson). This study was reported in line with the STROCSS criteria [8, 9]. Ethical Committee approval was obtained from Antalya Education and Research Hospital Ethics Committee with decision number 15/6 dated 28.02.2013, and the study was conducted in line with the Declarations of Helsinki.

Statistical Analysis

Statistical analyses were performed using SPSS (Version 22.0, SPSS Inc., Chicago, IL, USA). Descriptive statistics for continuous variables were reported as median (minimum – maximum) and mean ± standard deviation. Normality of group distributions

was assessed using the Kolmogorov-Smirnov and Shapiro-Wilk tests. Comparisons between pre- and post-operative values for EF, EDV, ESV, and SV were conducted using either the Paired Samples t-test or Wilcoxon signed-rank test, depending on whether parametric test assumptions were met. Limits of agreement for comparing the two methods (Teichholz and Simpson) were assessed using Bland-Altman plots. Statistical significance was set at p < 0.05.

Ethical Approval

This study was approved by the Ethics Committee of Antalya Education and Research Hospital (Date: 2013-02-28, No: 15/6).

Results

This study included 61 patients with a mean age of 45.2 ± 5.1 years and a mean BMI of 32.2 ± 3.1. Postop, the mean BMI was found to be 29.5 ± 2.9. Preoperative and postoperative measurements were compared, and the results are presented in Table 1. Images of the measurements for parameters calculated using the Teichholz and Modified Simpson methods are shown in Figures 1.A. and 1.B. Postoperative EF values measured by both the Simpson and Teichholz methods were statistically significantly higher compared to preoperative EF values (median post-pre: 68-62.5, p<0.001 and median post-pre: 73-66, p<0.001, respectively; Table 1). This increase indicates an improvement in cardiac function following surgery. The consistency in results obtained from these two different

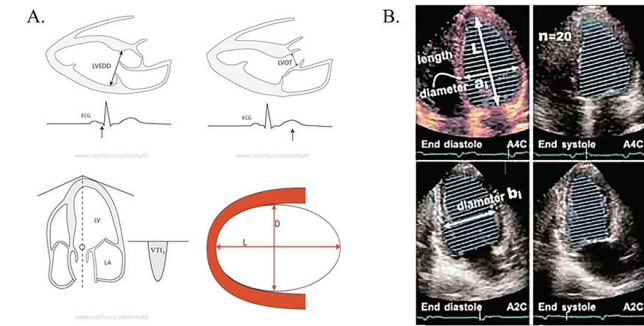


Figure 1. A. Teichholz's formula, B. Simpson's rule formula

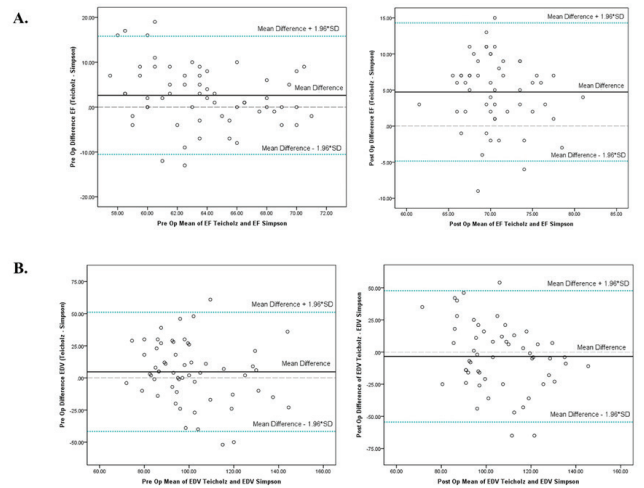


Figure 2. A. Bland-Altman plot of the difference between the pre-operative EF Teichholz-Simpson and the post-operative EF Teichholz-Simpson, B. Bland-Altman plot of the difference between the pre-operative EDV Teichholz-Simpson and the post-operative EDV Teichholz-Simpson

measurement methods supports the reliability of the findings. The postoperative EDV value measured by the Simpson method was statistically significantly higher than the preoperative EDV value (post-pre median: 105-94, $p=0.004$; Table 1), indicating an increase in cardiac filling volume postoperatively. However, there was no statistically significant difference between preoperative and postoperative EDV values measured by the Teichholz method ($p=0.646$; Table 1), possibly due to differences in measurement precision between the two methods. There was no significant difference in preoperative and postoperative ESV values measured by the Simpson method ($p=0.061$; Table

1), whereas the postoperative ESV value measured by the Teichholz method was statistically significantly lower than the preoperative ESV value (post-pre median: 27-34, $p<0.001$; Table 1). Postoperative SV values measured by both Simpson and Teichholz methods were statistically significantly higher compared to preoperative SV values (median post-pre: 72-57.5, $p<0.001$ and median post-pre: 74-65, $p<0.001$, respectively; Table 1). These increases indicate that the surgery effectively increased stroke volume and thus improved cardiac function. The agreement between preoperative and postoperative measurements of EF, EDV, ESV, and SV was analyzed using Bland-Altman plots, and the results are presented in Figure 2-A, Figure 2-B, Figure 3-A, and Figure 3-B. Upon examination of these plots, it was observed that EF, EDV, ESV, and SV values mostly fell within the limits of agreement. These plots demonstrate the consistency and reliability of both measurement methods in providing accurate results. The data indicate an overall improvement in postoperative EF, EDV, ESV, and SV values, with consistent results obtained from both measurement methods. The differences observed between the Simpson and Teichholz methods stem from variations in measurement techniques.

Discussion

In the literature, many studies examine the various medical and psychosocial outcomes of breast reduction surgery. These studies consistently show that the surgery provides significant improvements in both aesthetic and functional health. Hinson et al. (2024) conducted a study to assess patient-reported outcomes following bilateral breast reduction surgery. The study compared various techniques and found that all resulted in significant improvements, including reduced pain, enhanced physical function, and increased overall satisfaction. Although different techniques produced positive outcomes,

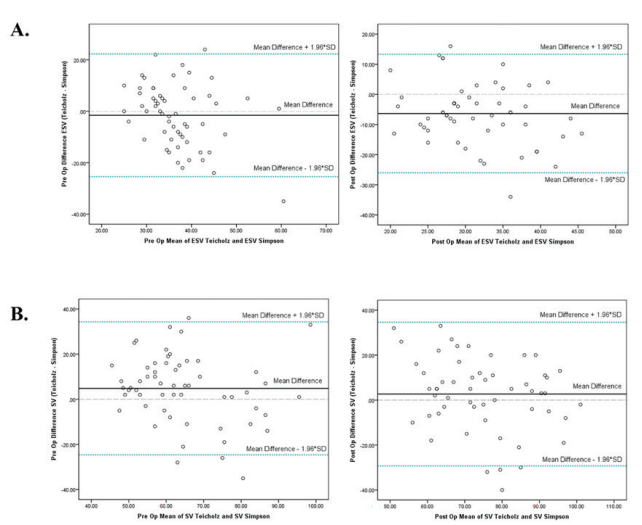


Figure 3. A. Bland-Altman plot of the difference between the pre-operative ES Teichholz-Simpson and the post-operative ES Teichholz-Simpson, B. Bland-Altman plot of the difference between the pre-operative SV Teichholz-Simpson and the post-operative SV Teichholz-Simpson

Table 1. Pre-post comparison of the measurements with two methods (Teichholz and Simpson)

Pre-Operation			Post-Operation		
		N		N	p - value
Simpson					
EF	Median (Min- Max)	60	62.5 (50 – 72)	68 (60 – 80)	<0.001*
	Mean ± SD		62.4 ± 5.6	68.3 ± 4.7	
EDV	Median (Min- Max)	58	94 (60 – 156)	105 (54 – 154)	0.004*
	Mean ± SD		98.2 ± 22.9	107.4 ± 23.5	
ESV	Median (Min- Max)	58	37 (20 – 78)	32 (16 – 54)	0.061*
	Mean ± SD		37.6 ± 10.9	34.5 ± 8.9	
SV	Median (Min- Max)	58	57.5 (38 – 98)	72 (35 – 106)	<0.001*
	Mean ± SD		62.2 ± 16.1	73.4 ± 16.8	
Teichholz					
EF	Median (Min- Max)	61	66 (55 – 75)	73 (63 – 83)	<0.001**
	Mean ± SD		65.1 ± 4.3	73.1 ± 4.2	
EDV	Median (Min- Max)	61	101 (70 – 162)	104 (68 – 140)	0.646*
	Mean ± SD		102.4 ± 18.7	103.6 ± 17.6	
ESV	Median (Min- Max)	61	34 (24 – 60)	27 (14 – 43)	<0.001*
	Mean ± SD		35.9 ± 7.9	28.0 ± 6.8	
SV	Median (Min- Max)	59	65 (45 – 115)	74 (51 – 102)	<0.001*
	Mean ± SD		66.9 ± 13.1	75.8 ± 13.1	

*: Wilcoxon signed-rank test, **: Paired samples t – test
Min: Minimum, Max: Maximum, SD: Standard Deviation

they varied in terms of patient satisfaction and functional improvement. This research provides valuable insights into optimizing surgical strategies to enhance patient benefits in breast reduction procedures [10]. C  rrea et al. (2019) assessed the quality of life in patients with breast hypertrophy before and after breast reduction surgery. The study found significant improvements postoperatively, including reductions in pain and discomfort, enhanced physical activity, and greater overall life satisfaction. Patients also reported better body image and increased self-confidence. These findings underscore that breast reduction surgery provides both physical relief and notable psychosocial benefits, significantly improving overall quality of life [11]. Guliyeva et al. (2021) conducted a systematic review to evaluate the impact of breast reduction surgery on pulmonary function. The review synthesized data from multiple studies and found that reduction mammoplasty generally leads to improvements in pulmonary function tests. Postoperative improvements include better respiratory parameters and reduced symptoms related to breathing difficulties. The study underscores that breast reduction surgery can positively affect lung function, contributing to overall patient well-being and potentially alleviating pulmonary symptoms associated with breast hypertrophy [7]. Coriddi et al. (2013) assessed satisfaction and well-being following breast reduction surgery using the BREAST-Q survey. Their findings indicate significant enhancements in satisfaction with breast appearance, as well as improvements in psychosocial, sexual, and physical well-being. The study underscores that overall patient satisfaction is closely linked to satisfaction with breast appearance, emphasizing the substantial quality of life improvements post-surgery [12]. Papanastasiou et al. (2019) conducted a study that reviewed the impact of breast reduction surgery on back pain and spine measurements. The study found that breast reduction significantly reduces back pain and improves spine measurements, highlighting the potential benefits of the surgery for spinal health [13]. Kraut et al. (2017) conducted a systematic review on the impact of breast reduction surgery on breastfeeding. Their findings highlight a varied impact, with some studies suggesting potential challenges to breastfeeding success, while others indicate minimal effects. Crucial factors identified include surgical techniques, postoperative recovery, and the availability of breastfeeding support. The study advocates for interventions such as preoperative counseling and postoperative support programs to improve breastfeeding outcomes. It emphasizes the necessity for further comprehensive studies to deepen our understanding of these impacts and inform clinical practices [14].

Gombaut et al. (2024) conducted a study on simultaneous free flap breast reconstruction combined with contralateral mastopexy or breast reduction, using the NSQIP database for analysis. They found that while operative times were longer, there were no significant differences in complication rates or hospital stay lengths compared to free flap reconstruction alone. The study concludes that this combined approach is safe and effective, particularly for achieving improved breast symmetry in breast cancer patients [15].

Holopainen et al. (2023) conducted a study that evaluated return-to-work times post-surgery. Most patients returned to

work within 4 to 6 weeks, though times varied based on age, preoperative health, and job type. Postoperative complications could extend return-to-work times. The study concludes that breast reduction surgery generally allows a timely return to work and effectively enhances patients' quality of life [16]. Riddle et al. (2020) explored the impact of metabolic syndrome on postoperative outcomes in breast reduction surgery patients. Their findings indicate that while patients with metabolic syndrome experienced longer surgical durations, there were no significant differences in hospital stay, reoperation rates, or readmissions compared to those without metabolic syndrome. This suggests that metabolic syndrome does not heighten complication rates and should not serve as a contraindication for breast reduction surgery [17].

In addition to these studies, our research significantly contributes to the literature by focusing on cardiac outcomes following breast reduction surgery. The increase in stroke volume (SV) and ejection fraction (EF) in both measurement methods shows a parallel trend. SV and EF increase inversely with end-systolic volume (ESV) but directly with end-diastolic volume (EDV). While SV and EF increase due to a significant decrease in ESV, the Simpson method attributes this to a notable increase in EDV. Both methods demonstrate a decrease in ESV and an increase in EDV, though no significant difference was found in EDV using the Teichholz method, and in ESV using the Simpson method.

Mean comparison tests indicate a significant increase in EF and SV using the Teichholz method, with ESV showing a significant decrease. Conversely, the Simpson method shows significant increases in EF, EDV, and SV. Comparison of the methods reveals differences in EDV and ESV results. Despite wide standard deviations in Bland-Altman graphs, high compatibility is observed between the methods. Interpretations of ICC and Bland-Altman compatibility statistics are crucial for method comparison. Based on compatibility results, both Teichholz and Simpson methods are suitable for assessing cardiac outcomes after breast reduction surgery.

Post-op BMI was found to be 29.5 ± 2.9 after breast reduction. The BMI difference pre-op and post-op could explain the increase in EF, which was highlighted in previous studies as well [2, 3]. Additionally, improvement in respiratory functions after breast reduction could be the cause of the cardiac EF change. Cardiac and respiratory mechanisms contribute to each other hemodynamically. Studies in the literature also reveal the recovery in respiratory functions via SFT before and after breast reduction.

In the study by Ergan Sahin et al. (2023), the effects of breast reduction surgery on electrocardiographic (ECG) parameters were examined, and significant improvements in atrial and ventricular conduction parameters were reported. Significant reductions in parameters such as PR duration, Pmax duration, and P wave dispersion (PWD) were observed postoperatively, indicating an improvement in cardiac conduction. Additionally, significant reductions were reported in ventricular conduction parameters such as TPe duration, TPe/QT ratio, and TPe/QTc ratio [18]. In our study, significant increases in ejection fraction (EF) values were observed postoperatively, measured by both the Simpson and Teichholz methods (median post-

pre: 68-62.5 and median post-pre: 73-66). These increases indicate an improvement in cardiac function following surgery. Similarly, postoperative end-diastolic volume (EDV) showed a significant increase when measured by the Simpson method (post-pre median: 105-94), while no significant difference was found with the Teichholz method. This discrepancy may be due to differences in the precision of the measurement methods. Additionally, significant increases in stroke volume (SV) values were observed postoperatively with measurements from both methods (median post-pre: 72-57.5 and median post-pre: 74-65). When the findings of both studies are considered together, the positive effects of breast reduction surgery on cardiac functions and conduction are demonstrated. While significant improvements in cardiac function parameters such as EF, EDV, ESV, and SV were observed in our study, improvements in ECG parameters were reported in the study by Ergan Sahin et al. (2023). These findings indicate that breast reduction surgery not only provides physical and aesthetic benefits but also has positive effects on cardiac function and conduction. The combined evaluation of the two studies more comprehensively demonstrates the positive impacts of breast reduction surgery on overall cardiac health.

Kramer et al. (2019) studied the impact of breast reconstruction surgery on ECG signals in women undergoing two-stage reconstruction with tissue expanders and silicone implants, finding no significant changes in ECG parameters. In contrast, our study shows improvements in cardiac function metrics after breast reduction surgery. These differing outcomes may result from variations in surgical approach and patient demographics. While Kramer's study highlights the cardiac safety of breast reconstruction, our research emphasizes the cardiac benefits of breast reduction. Further studies could explore the broader cardiovascular implications of these procedures [19].

The limitations of this study include several important factors. Firstly, the sample group was derived from a single center, potentially limiting the generalizability of our findings to a broader population. Furthermore, other study constraints include the relatively short follow-up period after surgery, which restricts a comprehensive assessment of long-term cardiovascular effects. Another limitation is the scarcity of studies investigating the effects of breast reduction on cardiac outcomes in the literature. Parameters such as PR interval, Pmax duration, and P-wave dispersion (PWD) were examined in the study by Ergan Sahin et al. (2023). In our study, however, we analyzed EF, EDV, ESV, and SV parameters. Due to the originality of our study and the lack of existing literature on this specific topic, it was presumed that the scope of our discussion section remained limited.

Conclusion

This study demonstrates that breast reduction surgery has significant positive effects on cardiac function, particularly in enhancing ejection fraction (EF) and stroke volume (SV). The findings indicate that these improvements are measurable through both the Teichholz and Modified Simpson methods, albeit with slight methodological differences in end-diastolic volume (EDV) and end-systolic volume (ESV) outcomes. The post-operative increase in EF and SV, coupled with a decrease in ESV, highlights the beneficial hemodynamic changes

following breast reduction. These changes can be partially attributed to the reduction in Body Mass Index (BMI) and the subsequent improvements in respiratory function, suggesting a holistic enhancement in patient health post-surgery. Given the high compatibility between the two echocardiographic methods used, both can be reliably employed to assess cardiac outcomes in similar surgical contexts. The significant cardiac benefits observed in this study underscore the dual aesthetic and functional value of breast reduction surgery, supporting its role in improving overall patient well-being. Further research may explore the long-term cardiovascular benefits and potential respiratory improvements to better understand the full scope of benefits associated with this common procedure.

In conclusion, breast reduction demonstrates both structural and functional myocardial changes and improves cardiac performance.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and Human Rights Statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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